(54) Title: BIALLELIC MARKERS DERIVED FROM GENOMIC REGIONS CARRYING GENES INVOLVED IN CENTRAL NERVOUS SYSTEM DISORDERS

(57) Abstract: The invention provides polynucleotides including biallelic markers derived from genes involved in CNS disorders and from genomic regions flanking those genes. Primers hybridizing to regions flanking these biallelic markers are also provided. This invention also provides polynucleotides and methods suitable for genotyping a nucleic acid containing sample for one or more biallelic markers of the invention. Further, the invention provides methods to detect a statistical correlation between a biallelic marker allele and a phenotype and/or between a biallelic marker haplotype and a phenotype.

BIALLELIC MARKERS DERIVED FROM GENOMIC REGIONS CARRYING GENES INVOLVED IN CENTRAL NERVOUS SYSTEM DISORDERS

FIELD OF THE INVENTION

5   The present invention is in the field of pharmacogenomics, and is primarily directed to biallelic markers that are located in or in the vicinity of genes that play a role in disorders of the brain and nervous system and to the uses of these markers. The present invention encompasses methods of establishing associations between these markers and central nervous system (CNS) disorders such as psychiatric disorders and neurodegenerative diseases as well as associations

10   between these markers and treatment response to a variety of therapeutic agents. The present invention also provides means to determine the genetic predisposition of individuals to such diseases and means to predict responses to such drugs.

BACKGROUND OF THE INVENTION

15   Advances in the technological armamentarium available to basic and clinical investigators have enabled increasingly sophisticated studies of brain and nervous system function in health and disease. Numerous hypotheses both neurobiological and pharmacological have been advanced with respect to the neurochemical and genetic mechanisms involved in central nervous system (CNS) disorders, including psychiatric disorders and neurodegenerative

20   diseases. However, CNS disorders have complex and poorly understood etiologies, as well as symptoms that are overlapping, poorly characterized, and difficult to measure. As a result future treatment regimes and drug development efforts will be required to be more sophisticated and focused on multigenic causes, and will need new assays to segment disease populations, and provide more accurate diagnostic and prognostic information on patients suffering from CNS

25   disorders.

A. Neurological Basis of CNS Disorders

Neurotransmitters serve as signal transmitters throughout the body; therefore, diseases that affect neurotransmission can have serious consequences. For example, for over 30 years the leading theory to explain the biological basis of many psychiatric disorders such as depression

30   has been the monoamine hypothesis. This hypothesis proposes that depression is partially due to a deficiency in one of the three major biogenic monoamines, namely dopamine, norepinephrine and serotonin. However, this hypothesis has been replaced by one that takes into account the overall function of the brain and no longer only considers a single neuronal system.

Dopamine

35   Dopamine is synthesized via the hydroxylation of tyrosine to dihydroxyphenylalanine (DOPA), involving the enzyme tyrosine hydroxylase (TH) and catechol O-methyl transferase (see Table 2: TH and COMT). Tyrosine hydroxylase is the rate-limiting enzyme in the synthesis

1

of catecholamines such as dopamine and norepinephrine. Dopamine and the enzymes involved in its biosynthesis and degradation are known to be involved in the pathophysiology of a depression, schizophrenia and Parkinson's disease. For example, it is believed tyrosine hydroxylase may be involved in the pathophysiology of psychiatric disorders and positive

5   associations have been reported for tyrosine hydroxylase gene markers in mood disorders. However, a recent study was unable to conclude tyrosine hydroxylase variants are related with depressive symptomatology in subjects affected by mood disorder (Serretti A. et al.; *American Journal of Medical Genetics* 81(2):127-130, 1998).

Dopamine, released from the nerve terminals, is largely recaptured by a re-uptake

10 mechanism involving dopamine transporter (DAT) (see Table 2: DAT). Following re-uptake, dopamine is metabolized by monoamine oxidases A and B (MAOA/B) (see Table 2: MAOA and MAOB). Monoamine oxidase A and B are critical enzymes in deamination of biogenic amines and may be involved in the pathophysiology of major psychoses, including mood disorder, Parkinson's disease and schizophrenia. Recently, evidence for genetic association between the

15 MAOA gene and bipolar mood disorder was demonstrated in a Caucasian population, but not seen in a Japanese population (Sasaki T. et al.; *Biological Psychiatry* 44(9):922-924, 1998).

Receptors for dopamine regulate dopaminergic neurotransmission. A plethora of dopamine receptors exist, including the presynaptic dopamine transporter and at least five pharmacologic subtypes (D_1 -which is linked to the enzyme adenyl cyclase, D_2 -not linked to

20 adenyl cyclase, D_3, D_4, and D_5). Classically, the most extensively investigated dopamine receptor is the D_2 receptor, as it is stimulated by dopaminergic agonists for the treatment of Parkinson's disease and blocked by dopamine antagonist neuroleptics for the treatment of schizophrenia (see Table 2: DRD2). Recently, other dopamine receptors, particularly the D_4 receptor, have become targets for new antipsychotics in the treatment of Parkinson's disease (see

25 Table 2: DRD4). It appears the interaction of all or some of the dopamine receptors play a role in many CNS disorders. However, only a limited number of studies investigating the association of such disorders with genes of the dopaminergic pathway have been completed and often with conflicting results.

Norepinephrine

30 The noradrenergic system is known to play a large role in the determination of mood, dysfunction of contributes to the "functional" disorders of depression, mania and anxiety. It is believed depressed patients are unable to produce sufficient norepinephrine in some parts of the brain for neuronal transmission, while mania may result from excessive activity or sensitivity of this system.

35 The amino acid tyrosine, having been actively taken up by adrenergic neurons, is converted to DOPA by means of tyrosine hydroxylase. DOPA is then converted to dopamine and later into norepinephrine in the synaptic vesicles. Conversion of norepinephrine to

mediated by more than one neurotransmitter; for example, the serotonergic system may co-exist with other neurotransmitter in the same synapses.

Gamma aminobutyric acid (GABA)

Gamma aminobutyric acid (GABA) is an important amino acid which functions as the most prevalent inhibitory neurotransmitter in the central nervous system. Gamma aminobutyric acid works in partnership with a derivative of Vitamin B-6, pyridoxine, to cross from the axons to the dendrites through the synaptic cleft, in response to an electrical signal in the neuron and inhibits message transmission. This helps control the nerve cells from firing too fast, which would overload the system.

The gamma aminobutyric acid (a) receptor (see Table 2: GABRA5 and GABRG2) appears to play a key role in modulating anxiety and could be involved in either the etiology or the pathogenesis of anxiety disorders (Crowe et al. *Am J Psychiatry* 154:8). A benzodiazepine binding site is located on this receptor, and ligands that bind to this site can either increase or decrease anxiety.

Growth associated protein (GAP43)

Growth associated protein (GAP43) is localized exclusively to nerve tissue and is known to play a role in synaptic transmission and membrane permeability. The expression of GAP43 is associated with mammalian peripheral nerve regeneration (Kosik et al. *Neuron* 1:127-132, 1988). A polymorphism in the 3'-untranslated region of GAP43 is found at slightly lower frequencies in Alzheimers and Parkinson's patients (Poduslo. *Hum Genet.* 92:635-636, 1993).

Subreceptor Activity

The activity of subreceptors has also been investigated in recent years for its role in a wide range of CNS disorders. When neurotransmitters bind to receptors on the membranes of postsynaptic neurons, they elicit a target response in the cell via a second or third messenger. Several different messenger chemicals are known including cyclic adenosine monophosphate (AMP). G proteins serve as signal transduction subunits in the cyclic AMP pathway (see Table 2: Gbeta3). G protein coupled receptors are thought to have seven membrane spanning domains and have been divided into 2 subclasses: those in which the binding site is in the extracellular domain for example receptors for glycoprotein hormones, such as thyroid stimulating hormone (TSH) and follicle stimulating hormone (FSH) and those in which the ligand binding site is likely to be in the plane of the 7 transmembrane domains for example rhodopsin and receptors for small neurotransmitters and hormones for example muscarinic acetylcholine receptor. However, orphan G-protein coupled receptor (see Table 2: HM77) does not contain N-linked glycosylation sites near the N-terminus like other members of this protein family.

There is evidence that various monoamine or monoaminergic receptors are able to alter cyclic AMP levels through the same G protein. Therefore, G proteins serve as an important cross-talk mechanism between transmitter systems in the CNS. An abnormality in a G protein or

The anxiolytic effects of corticotrophin-releasing factor appear to be mediated by the activation of the central noradrenergic system. A CRF-positive projection has been identified linking limbic structures to the noradrenergic locus ceruleus, stimulation of which plays an important role in emotional memory and increases tyrosine hydroxylase activity. Therefore,

5   primary or secondary dysfunction of corticotrophin-releasing factor would be expected to initiate a cascade of maladaptations.

Glucocorticoids and mineralocorticoids are both classes of steroid hormones that play an important role in the HPA axis; and have therefore been implicated in the pathophysiology of various psychiatric disorders and neurodegenerative diseases (see Table 2: GRL and MLR).

10   Glucocorticoids exert numerous effects on metabolism, reproduction, inflammation and immunity. In addition, glucocorticoids serve as the primary negative feedback mechanism that regulates the HPA axis. Mineralocorticoids maintain electrolyte balance by regulating salt and water retention in the kidneys.

Brain-derived neurotrophic factor (see Table 2: BDNF) is a member of a group of

15   proteins that includes neurotrophin-3/4/5 and nerve growth factor (NGF) and are believed to play a role in the etiology of a number of CNS-related disorders including schizophrenia and Parkinson's disease (Hawi et al. *Psychiatry Research* 81: 111-116, 1998 and Gasser et al. *Annals of Neurology* 36(3)387-396, 1994). BDNF plays an important role in promoting growth and maintenance during normal development and differentiation of the vertebrate system (Hanson et

20   al. *Genomics* 13: 1331-1333, 1992). Further, it is believed BDNF has an effect on the differentiation of dopaminergic and serotonergic neurons (Studer et al. *Euro. J. of Neuroscience* 7: 223-233, 1995).

C. Examples of CNS Disorders

Neurotransmitter and hormonal abnormalities are implicated in disorders of movement

25   (e.g. Parkinson's disease, Huntington's disease, motor neuron disease, etc.), disorders of mood (e.g. unipolar depression, bipolar disorder, anxiety, etc.) and diseases involving the intellect (e.g. Alzheimer's disease, Lewy body dementia, schizophrenia, etc.). In addition, Neurotransmitter and hormonal abnormalities have been implicated in a wide range of disorders, such as coma, head injury, cerebral infarction, epilepsy, alcoholism and the mental retardation states of metabolic

30   origin seen particularly in childhood.

Schizophrenia

In developed countries schizophrenia occurs in approximately one per cent of the adult population at some point during their lives. There are an estimated 45 million people with schizophrenia in the world, with more than 33 million of them in the developing countries.

35   Moreover, schizophrenia accounts for a fourth of all mental health costs and takes up one in three psychiatric hospital beds. Most schizophrenia patients are never able to work. The cost of schizophrenia to society is enormous. In the United States, for example, the direct cost of

forms and display different symptoms, the classification of bipolar disorder has been the subject of extensive studies resulting in the definition of bipolar disorder subtypes and widening of the overall concept to include patients previously thought to be suffering from different disorders. Bipolar disorders often share certain clinical signs, symptoms, treatments and neurobiological

5   features with psychotic illnesses in general and therefore present a challenge to the psychiatrist to make an accurate diagnosis. Furthermore, because the course of bipolar disorders and various mood and psychotic disorders can differ greatly, it is critical to characterize the illness as early as possible in order to offer means to manage the illness over a long term.

        Diagnosis of bipolar disorder can be very challenging. One particularly troublesome

10   difficulty is that some patients exhibit mixed states, simultaneously manic and dysphoric or depressive, but do not fall into the DSM-IV classification because not all required criteria for mania and major depression are met daily for at least one week. Other difficulties include classification of patients in the DSM-IV groups based on duration of phase since patients often cycle between excited and depressive episodes at different rates. In particular, it is reported that

15   the use of antidepressants may alter the course of the disease for the worse by causing "rapid-cycling". Also making diagnosis more difficult is the fact that bipolar patients, particularly at what is known as Stage III mania, share symptoms of disorganized thinking and behavior with bipolar disorder patients. Furthermore, psychiatrists must distinguish between agitated depression and mixed mania; it is common that patients with major depression exhibit agitation,

20   resulting in bipolar-like features.

        For both schizophrenia and bipolar disorder, all the known molecules used for treatment have side effects and act only against the symptoms of the disease. There is a strong need for new molecules without associated side effects or reduced side effects which are directed against targets that are involved in the causal mechanisms of schizophrenia and bipolar disorder.

25   Therefore, tools facilitating the discovery and characterization of these targets are necessary and useful.

        The aggregation of schizophrenia and bipolar disorder in families, the evidence from twin and adoption studies, and the lack of variation in incidence worldwide, indicate that schizophrenia and bipolar disorder are primarily genetic conditions, although environmental risk

30   factors are also involved at some level as necessary, sufficient, or interactive causes. For example, schizophrenia occurs in 1% of the general population. However, if a subject has one grandparent with schizophrenia, the risk of getting the illness increases to about 3%, while one parent with Schizophrenia increases risk to about 10%. When both parents have schizophrenia, the risk rises to approximately 40%. Consequently, there is a strong need to identify genes

35   involved in schizophrenia and bipolar disorder. The knowledge of these genes will allow researchers to understand the etiology of schizophrenia and bipolar disorder and could lead to

may be selected from the following biallelic markers: 99-28788-300, 99-32061-304, 99-32121-242, 19-14-241, 19-28-136, 16-50-196, 19-58-162, 19-9-45, 20-205-302, 24-243-346, 99-27207-117, 99-28110-75, 99-28134-215, 99-32181-192, 19-17-188 and 19-19-174; Optionally, the identity of the nucleotides at the biallelic markers in everyone of the sequences of SEQ ID NO:
5   1-542 is determined in steps a) and b).

A ninth embodiment of the present invention encompasses methods of detecting an association between a haplotype and a phenotype, comprising the steps of: a) estimating the frequency of at least one haplotype in a trait positive population according to a method of estimating the frequency of a haplotype of the invention; b) estimating the frequency of said
10   haplotype in a control population according to the method of estimating the frequency of a haplotype of the invention; and c) determining whether a statistically significant association exists between said haplotype and said phenotype. In addition, the methods of detecting an association between a haplotype and a phenotype of the invention encompass methods with any further limitation described in this disclosure, or those following, specified alone or in any
15   combination: Optionally, said CNS disorder-related biallelic marker may be in a sequence selected individually or in any combination from the group consisting of SEQ ID NO: 1-542, and the complements thereof; Optionally, said CNS disorder-related biallelic markers may be selected individually or in any combination from the biallelic markers described in Table 7; Optionally, said CNS disorder-related biallelic marker may be selected from the following
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25   19-46-322, 99-32131-312, 99-32065-303, 19-44-251, 19-29-303, 18-355-67, 18-353-267, 18-338-305, 16-88-185, 24-243-346, 99-62531-351, 99-54279-152, 99-28171-458, 99-28173-395, 18-186-394, 8-15-126, 99-2409-298, 99-28722-90 and 99-32306-409; Optionally, said CNS disorder-related biallelic marker may be selected from the following biallelic markers: 99-28788-300, 99-32061-304, 99-32121-242, 19-14-241, 19-28-136, 16-50-196, 19-58-162, 19-9-45, 20-
30   205-302, 24-243-346, 99-27207-117, 99-28110-75, 99-28134-215, 99-32181-192, 19-17-188 and 19-19-174; Optionally, said control population may be a trait negative population, or a random population; Optionally, said phenotype is a CNS disorder, a response to an agent acting on a CNS disorder, or side effect to an agent acting on a CNS disorder; Optionally, the identity of the nucleotides at the biallelic markers in everyone of the following sequences: SEQ ID NO: 1-542 is
35   included in the estimating steps a) and b).

A tenth embodiment of the present invention encompasses polypeptides encoded by SEQ ID NO: 543 or 544, as well as antisense analogs thereof and biologically active and

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307

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